69-1632

FEASIBILITY OF AN ARTILLERY SILENCER

FINAL REPORT

TECHNICAL REPORT

By

Mark J. Salsbury

June 1969

U S ARMY WEAPONS COMMAND
RESEARCH & ENGINEERING DIRECTORATE
ARTILLERY SYSTEMS LABORATORY

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Artillery Advanced Systems Group

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D.A. Project No. 1-L-0-13001-A-91A

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ABSTRACT

This Technical Report summarizes the engineering and testing effort expended to determine the feasibility of using a mechanical muffler to substantially reduce artillery test firing noise. The required and/or desired capabilities for such a silencer system were established and an experimental system was designed and fabricated. The test procedure included both objective and subjective testing to determine the effectiveness of this silencer. Test results are presented and it is concluded that a mechanical silencer can be made to attenuate 155mm artillery weapons; its size and the complex elevating system required would however make such a system impractical.

FOREWORD

This project was funded under AMCMS Code 5016.11.84400.03. The work was authorized under D. A. Project No. 1-L-0-13001-A-91A.

The assistance received from Mr. Walter Pape, of the Tank Systems Laboratory, in obtaining M68 cannon data is hereby acknowledged.

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OBJECT

The object of this study was to determine feasibility of a mechanical muffler to substantially reduce the noise level of 155mm weapons.

GENERAL DISCUSSION

Testing of 155mm weapons was discontinued over 10 years ago at Rock Island Arsenal because of damage complaints received from the surrounding communities.

Since this time, sound and vibration studies have been made with the 105mm Howitzer. These studies showed that with this weapon, only 4 percent of the minimum vibration intensity required for even minor structural damage was experienced in the areas of complaint. From this fact, it can be concluded that the possibility of damage being caused by the larger weapon is remote. However, the peak sound levels produced by the 155mm weapons justify the complaints from the viewpoint of general annoyance.

At the present time, 105mm howitzers are tested at the Arsenal with general public acceptance; except for isolated cases when atmospheric conditions cause the 105's blast to focus on a specific location.

The task, therefore, is to develop an attenuation system which will reduce the sound level of 155mm weapons down to at least that of the 105mm howitzer and still meet all other testing requirements.

The required and/or desired capabilities of such an attenuation system are the following:

(a) It must provide enough attenuation to permit testing under all atmospheric conditions. (Desired)

(b) The system may not alter the weapon's normal firing reactions. (Required)

(c) It must be flexible enough to handle all artillery and tank mounted weapons up to and including the 155mm at all angles of elevation. (Required)

(d) The system must not interfer with either the instrumentation or weapon laying procedures. (Required)

(e) It should be capable of handling weapons equipped with muzzle brakes. (Required)

TEST EQUIPMENT

Weapon: The weapon used for this study was an M102, 105mm Howitzer.

Silencer: The test silencer used was a multi-chambered type, much like those used on small arms. (See Figure 1). It is approximately 20 feet long and 5 feet in diameter. The basic difference between this design and conventional silencers is the distribution of the muzzle gases. Because the silencer is not attached to the weapon and because large barrel clearances are provided to accommodate weapon hop, only a portion of the muzzle gases are forced through the full series of chambers; the remaining gases are exhausted at the gun end of the silencer.

To minimize rearward exhaust, an internal tube and baffles with oversized ports are placed at the gun end of the silencer. This configuration forces most of the incoming gases directly into the central chambers.

INSTRUMENTATION

1. Peak sound pressure levels were recorded in decibels (re .0002 dynes/cm^2) with two types of pickups:

(a) The Bruel & Kjaer, one quarter inch microphone, type 4135/36 and associated cathode follower which was powered by a type 2801 microphone power supply.

This equipment was calibrated as a system with the Bruel & Kjaer, type 4220 pistonphone.

(b) A General Radio Model 1551-C Sound Level Meter in series with the 1556-B Impact-Noise Analyzer.

This equipment was calibrated as a system with a General Radio, type 1562-A Sound Level Calibrator.

2. The recording equipment used with both pickups was a Tektronik Oscilloscope, Model 549 with a type-m pre-amplifier plug-in unit. Polaroid photographs were taken of the oscilloscope traces.

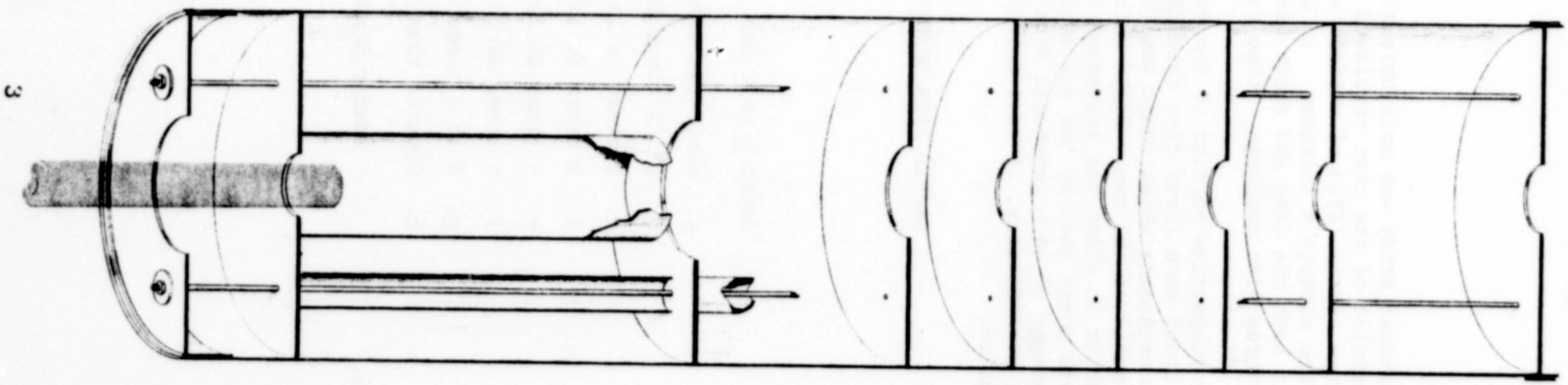


FIGURE 1

EXPERIMENTAL ARTILLERY SILENCER

PROCEDURE

The silencer study was both objective and subjective. The objective portion of the test consisted of measuring the peak sound pressure levels (SPL) of various weights of charges (zones) fired with and without a silencer. In addition to this, the weapon was fired in both the long and short recoil modes and also with the silencer covered with sandbags. (See Figure 2).

In the subjective portion of the test, an unsilenced round and a silenced round were fired five seconds apart and the subjects were required to determine which round was the louder and also the "loudness" ratio of the two. Eight such pairs of shots were fired in each session in which the sequences of the rounds were varied. A sample data sheet used by the subjects is shown below. While the small amount of data generated from this test does not have statistical significance, it does provide valuable insight to the overall problem.

SAMPLE DATA SHEET FORM

Location

____

Round 1 or 2 is.

a. About the same

b. 1 1/2 times as loud

c. 2 times as loud

d. 3 times as loud

e. 4 times as loud

f. 5 times as loud

g. 6 to 8 times as loud

h. Greater than 8 times as loud

Pair No.	Louder Round	Ratio
1		
2		
3		
4		
5		
6		
7		
8		

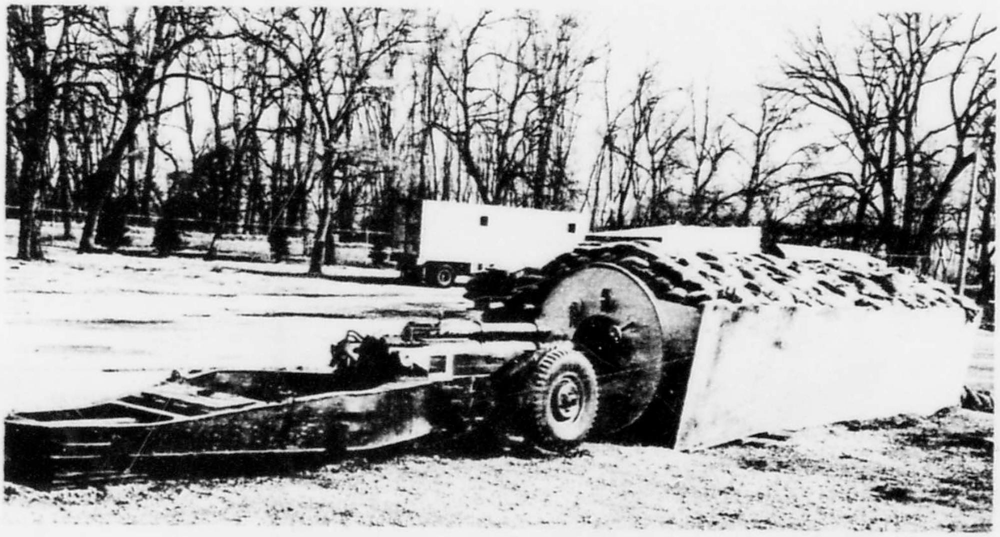
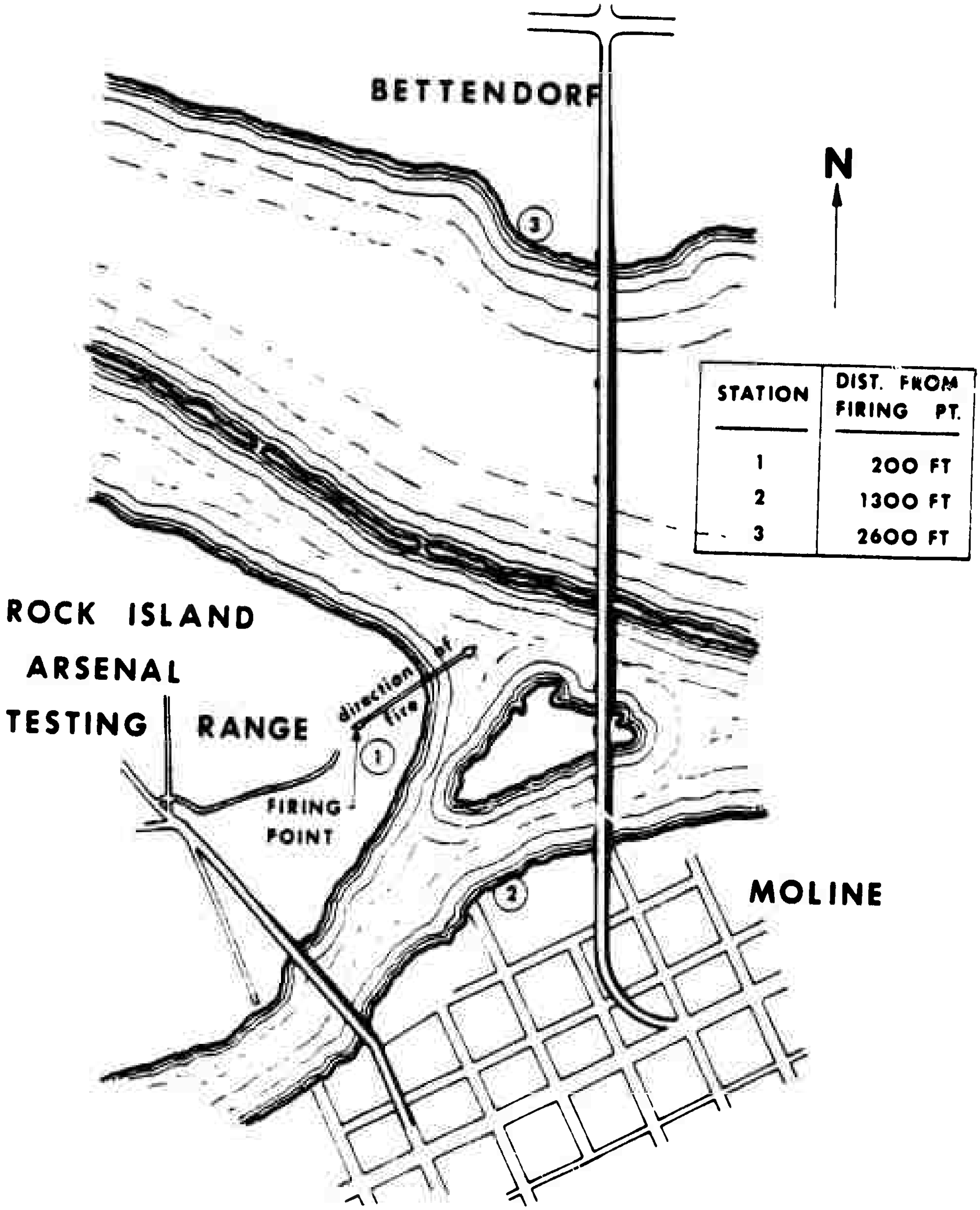


Figure 2
Artillery Silencer Covered With Sand Bags

Three test stations were used in both portions of the study. Test station one was located at the Test and Evaluation Range, 200 feet to the right of the weapon. Station two was at the Water Works in Moline, Illinois, a distance of 1,300 feet from the weapon. Station three was located at the Municipal Boat Dock in Bettendorf, Iowa, 2,600 feet from the weapon. The locations of these sites, relative to the weapon and line of fire, are shown in Figure 3.

A separate study was conducted by the Tank Systems Laboratory in which the silencer was tested with the M68, 105mm, Tank Cannon. Because of testing regulations, this weapon could not be fired without the silencer (too loud) and only sand projectiles could be used. As a result, the actual attenuation could not be estimated.

Although this study had a completely different objective, the data acquired is certainly germane to our problem and therefore is incorporated into this report.



STATION	DIST. FROM FIRING PT.
1	200 FT
2	1300 FT
3	2600 FT

FIGURE 3
SOUND LEVEL TESTING RANGES

RESULTS

Results obtained from the various phases of this study are summarized in Tables I - IV.

TABLE I
Peak Sound Pressure Levels of an 105mm Howitzer

Charge Zone	Test Station	Status	Unsilenced SPL (db)*	Silenced SPL (db)*	Attenuation (db)*
3	1	Long Recoil	143	120	23
	3	Long Recoil	103	SPL within ambient noise level (74 - 86 db)	17+
5	1	Long Recoil	147	126	21
	3	Long Recoil	112	93	19
7	1	Long Recoil	150	139	11
	1	Short Recoil	150	141	9
	1	Short Recoil (silencer covered with sandbags)	150	140	10
	2	Short Recoil	129	120	9
	2	Short Recoil (silencer covered with sandbags)	126	117	9
	3	Long Recoil	118**	103	15
	3	Short Recoil (silencer covered with sandbags)	126**	106	20

* SPL in decibels (re .0002 dynes/cm^2)

** These readings (118 and 126) were taken on two different days and do not represent typical data variation.

TABLE II

Subjective Estimates of Loudness Ratios of Silenced and Unsilenced Rounds - Zone 7 Rounds

Status		Station 1	Station 2	Station 3
Long Recoil	Silenced / Unsilenced	1/2.0	1/1.8	1/2.6
Short Recoil	Silenced / Unsilenced	1/2.0	1/2.2	1/2.5
Short Recoil Sandbags	Silenced / Unsilenced	1/1.8	1/2.0	1/3.0

TABLE III

Outline of Firings Tests Using the 105mm, M68 Cannon

Test No.	Rds Fires	Powder Charge	Silencer Modifications	Damage to Silencer
1	1 1	50% 75%	None	75% charge blew out baffles and front end
2	1 1	50% 75%	Without baffles, reinforced front end with vent around circumference	75% charge fractured cylindrical hull in two places
3	1 1	50% 75%	Without baffles, no vent around end, 90 lb. bag of water in 17 in. dia. tube (Pos a - Fig. 4)	Fractured 17 in. dia. tube and its welded joint with end plate
4	1	50% 75%	Without baffles, 90 lb. bag of water in front of 17 in. dia. tube, (Pos b - Fig. 4) bag suspended by bar fastened to top of tube	75% charge blew bar, used for suspending water bags, loose from fastenings
5	1 1	100%	Same as for Test 4 except with three, 90 lb. bags of water in front of 17 in. dia. tube. (Pos b Fig. 4) Same as above but with a 25 lb. bag of water in exit hole (Pos c - Fig. 4)	No apparent damage Approx. 4 ft. of the 17 in. dia. tube destroyed

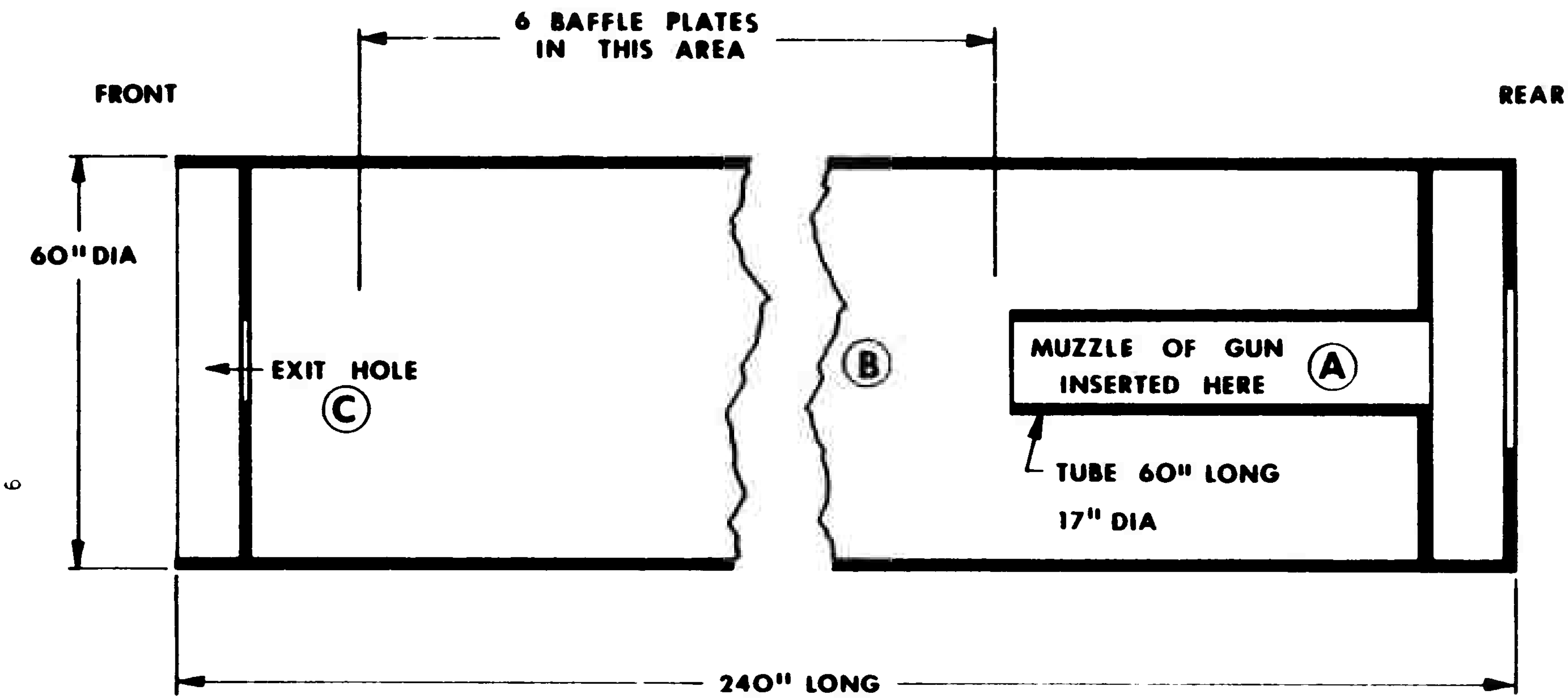


FIGURE 4

ARTILLERY SILENCER CROSS SECTION SCHEMATIC DIAGRAM

TABLE IV

Summary of Firing Noise Survey of the M68 Cannon

Test No.	Weapon*	Powder Charge	Sound Pressure Level - db		Listener Survey	
			Sta. 1	Sta. 3	Sta. 3	Sta. 2
1	Howitzer Cannon	100% 50%	146.5 136.5	117 110	Howitzer Louder	Howitzer Louder
	Howitzer Cannon	100% 75%	146 140.5	118 105	Howitzer Louder	Howitzer Louder
2	Howitzer Cannon	100% 50%	147.5 143.5	119 121	Equally Loud	Equally Loud
	Howitzer Cannon	100% 75%	147 147.5	119 121.5	Cannon Louder	Cannon Louder
3	Howitzer Cannon	100% 50%	148 147	--- ---	---	---
4	Howitzer Cannon	100% 50%	151 140	119.5 104	Howitzer Louder	Howitzer Louder
	Howitzer Cannon	100% 75%	152 144	120 108.5	Howitzer Louder	Howitzer Louder
5	Howitzer Cannon	100% 100%	138 136.5	132 125	Equally Loud	Howitzer Louder
	Howitzer Cannon	100% 100%	136 131.5	124 123	Howitzer Louder	Howitzer Louder

* Cannon = 105mm Cannon, M68, fired into silencer
Howitzer = 105mm Howitzer, M102, without silencer

DISCUSSION OF RESULTS

1. Attenuation is much greater for Zones 3 and 5 than for Zone 7. The possible reasons for this are listed and evaluated below.

a. Cause

Zone 7 charges cause the gun tube to recoil much farther out of the silencer, permitting more gas to escape directly into the atmosphere.

a. Evaluation

Zone 7 charges were fired in both the long and short recoil modes with no change in attenuation.

b. Cause

Zone 7 charges transmit more energy through the unsupported walls of the silencer than do the lower zones.

b. Evaluation

The silencer was covered with sandbags. This stopped silencer wall vibrations but had no effect on peak SPL's.

c. Cause

Attenuation is a strong function of the acoustical energy input, where the acoustical energy equals the total propellant energy minus the energies transferred to the weapon and projectile.

c. Evaluation

If this were the case, the attenuation for the Zone 5 would be far less than that for the Zone 3, since,

$$\frac{\text{Energy Zone 5}}{\text{Energy Zone 3}} > \frac{\text{Energy Zone 7}}{\text{Energy Zone 5}}$$

d. Cause

Zone 3 and 5 produce subsonic projectile velocities while the Zone 7 is supersonic. It is therefore possible that the projectile noise (ballistic crack) is the limit of attenuation.

d. Evaluation

This theory appears valid for the following reasons:

(1) The peak SPL of the Zone 7 projectiles shock wave was computed for Station 1 and the theoretical values were in close agreement with actual measurements.

(2) Although having up to 6 times the acoustical energy input of the howitzer, the M68 Cannon, firing sand rounds through the silencer, produced db levels comparable to the silenced howitzer with steel projectiles.

2. Although valid readings are impossible when structural failures occur, it is evident from the M68 subjective data that the silencer worked much better with the interior baffles than without them.

3. The use of water bags within the silencer appears to achieve the desired attenuation. However, this approach would hinder test procedures too much to be a suitable solution to any large scale testing.

4. A comparison of the objective and subjective data is shown below for the Zone 7 charges.

		Average Estimated Loudness Ratio	Average Measured Pressure Ratio
Station 1	Silenced / Unsilenced	1/1.9	1/3.2
Station 2	Silenced / Unsilenced	1/2.0	1/2.8
Station 3	Silenced / Unsilenced	1/2.7	1/8.0

Even though the frequency spectrums of the silenced and unsilenced weapon noises are certainly different and perhaps give rise to entirely different sensations of loudness, the subjects' estimates of loudness were typical of those found in this type of test. That is, the loudness sensation of a sound was nearly proportional to the logarithm of its intensity.

CONCLUSIONS

1. Since the M68 Cannon was silenced down to slightly below the db level of the 105mm Howitzer, it is evident that more attenuation will be needed to accommodate the 155mm weapons which have 3.5 times the acoustical energy input of the M68 Cannon and over 20 times that of the 105mm Howitzer.

2. If it is proven in later studies that a silencer's relative efficiency is not a strong function of energy input and projectile noise is in fact the limit of attenuation, then:

(a) Our test silencer attenuates weapon blast by 20+ db for all charge weights as it did for Zones 3 and 5.

(b) Projectile noise must be eliminated either by inclosing the projectile flight path or by using only disintegrating projectiles.

3. Since more attenuation is needed, a silencer for the 155mm weapons will have to be at least as large as our test model.

4. With silencers of this type, maximum attenuation is usually about 30 decibels. It is also generally true that any additional attenuation above 20 decibels is achieved only at the expense of a disproportional amount of design complexity.

5. Typical methods of optimizing a silencer's efficiency and the compatibility of these methods with our overall requirements are listed below:

a. Normally, a silencer is connected to the gun muzzle and exhausts all gases forward.	a. Gun reactions must be independent of the silencer.
b. Increase internal volume.	b. Since an artillery silencer must be elevated at least 30 feet to be aligned with gun tubes at maximum elevation, it is felt that the size of our test model may already exceed practical limits.
c. Up to an optimum number, the addition of interior baffles increases attenuation.	c With silencers of this size, the baffles weigh about 500 lbs apiece.
d. The silencer's chambers are filled with wire mesh, fibre glass, etc.	d. Again weight is a problem but more important is the fact that disintegrating projectiles must be used for elevated firings which would either clog or destroy these materials.
e. By keeping the projectile port diameters to a minimum, blowby is reduced and attenuation is increased.	e. If steel rounds are to be fired at 0° elevation, safety demands that extremely large port clearances be maintained to allow for bore sighting errors.

6. Additional structural problems are introduced when disintegrating projectiles are used, as evidenced by the M68 test. Where normally the silencer is only subjected to the gas ejection period impulse; now, a good portion of the projectile impulse is transmitted to it, assuming only a small percentage of sand will traverse the silencer's entire length with any appreciable velocity.

7. To summarize a mechanical silencer can be made to attenuate 155mm weapons but its size, and that of its associated elevating system, would be too large and complex to be practical.

RECOMMENDATIONS

1. Tests should be conducted to determine the significance of the 155mm projectile's shock wave at distances of 1,000 feet and greater. This will be an important consideration as far as any approach to artillery attenuation is concerned.

2. Sound level readings of the 155mm weapons should be made side by side with those of the 105mm howitzer to establish an absolute value of the attenuation requirement.

3. As for another approach to the problem, it is recommended that the weapon be either partially or completely enclosed and projectile noise eliminated by those methods cited earlier.

It is felt that the existing projectile pit at the Arsenal's T & E Range could be used to quickly determine the feasibility of this method. If this appraoch proves successful, the pit could be modified to accommodate high elevation firings.

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3. Sound Pressure Levels
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